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EM SURVEY AT
CABOT CORPORATION PLANT,
TUSCOLA, ILLINOIS

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INTRODUCTION

Hydropoll, Inc. was requested by the Cab-O-Sil Division of Cabot Corporation to conduct an EM (Electromagnetic Conductivity) survey at its plant located in Tuscola (Douglas County), Illinois. The primary objective of the survey is to assist delineating the extent of groundwater contamination from both the RCRA impoundment and other potential sources at the plant. Furthermore, the results of the EM survey may be used to aid in the siting of further monitoring wells, if necessary.

Background

The Cab-O-Sil Division of Cabot Corporation has been operating at the present location since 1958. The main by-product of the fumed silica process at the Tuscola plant is hydrochloric acid. A dilute waste stream ($\approx$2% HCl) has been stored in a two-cell impoundment (RCRA impoundment) prior to injection in one of the two deep wells at the plant since 1966. Before then the acidic waste had been stored in several areas located east and southeast of the present impoundment prior to underground injection.

In addition to the RCRA impoundment above, a solids disposal area and a solid waste disposal site exist east of the RCRA impoundment. The dredged solids from the impoundment had been placed onto an area east of the impoundment. A solid waste disposal site is present further east of the impoundment. This site is equipped with an underdrain system to collect leachate and to convey it to the RCRA impoundment. The solid waste disposal site includes primarily broken concrete, asphalt, pipes and silicon metal ash residue from past operation. A few tank storage areas are located on north of the impoundment. Furthermore, a fertilizer company was operating near the northern barbed wire fence of the plant.

HYDROGEOLOGY

Approximately 200 ft. thick unconsolidated Pleistocene deposits overlay the Pennsylvanian bedrock near the plant (Kempton et al., 1982). The predominant rock type in these deposits is the glacial till which is a mixture of clay and silt.

The soil analyses from the monitoring wells indicate that the till is primarily of silty clay/clayey silt. Its vertical hydraulic conductivity, measured in laboratory, averaged 8.3×10^{-9} cm/sec. Horizontal permeability ranged from 5.8×10^{-5} to 6.6×10^{-5} cm/sec. based on two field measurements. No sand and gravel aquifer of the Pleistocene was found in the plant monitoring wells. Little perched water, however, occurs in weathered and fractured parts of the surficial tills, just above the unweathered till.

Thirteen monitoring wells, ranging from 16 to 52.5 ft. in depth, were installed at the Cabot Corporation plant between December 1981 and April 1984 (Hydropoll, 1984a). Of these, G109 and G113 are relatively deep and the rest are relatively shallow. Construction details of and analysis results of samples from the monitoring wells were submitted previously by Hydropoll in various assessment programs and quarterly groundwater assessments.

Depth to groundwater is shallow, between 2.17 and 4.33 ft., in the monitoring wells (Hydropoll, 1984b). Regional groundwater flow direction is towards east-southeast. The RCRA impoundment is leaking and migration of waste fluids from the impoundment has formed a groundwater mound under the impoundment. It has been estimated that a drop of fluid from the impoundment has traveled 325 ft. in the regional flow direction since 1966. In the above estimate, it was assumed that the impoundment is the only source (Hydropoll, 1984b).

Analyses of the water samples from the monitoring wells demonstrate groundwater contamination near the impoundment. The contamination extends eastward. However, the groundwater along the norther half of the eastern boundary of the plant has not been contaminated (Hydropoll, 1984b).

EM TERRAIN CONDUCTIVITY SURVEY

An EM terrain conductivity survey was conducted on September 19, 20, and 21, 1984 using a Geonics EM 31 conductivity meter. The instrument is portable and operated by one person. The maximum effective depth of exploration is approximately six meters or 19.7 ft. (Geonics Ltd, 1984). EM 31 conductivity meter reads terrain conductivity in millimhos/meter. The survey has been conducted on a station by station basis. Initial parts of the grid system were laid out by Cabot Corporation personnel.

Background

The EM 31 equipment measures the combined apparent conductivity of the soil material and the fluid contained in the soil pores in millimhos/meter. This method is very similar to conventional resistivity methods in which resistivity is measured in ohm-meter.

The measured apparent conductivity is the result of both the lithologic character of the underlying geological materials (rocks) and the quality of the pore water. Assuming the lithogoical characters of the rocks do not change in short distances (between measurement stations), difference in apparent conductivities measured at the stations should be primarily related to variations in mineralization of the groundwater, except where conductive solid contaminants may be present.

In conductivity surveys, such as EM 31, compact glacial till, clay, and shale cause higher readings than the unconsolidated sand and gravel, or sandstone and limestone. Similarly, highly mineralized water in the pores of the rocks causes higher conductivity readings than that of fresh water in the pores of similar materials.

Reed et al (1981) reported that the layering of earth materials of greatly different resistivities (or conductivities) distorts the electrical field and presence of saline (highly mineralized) pore water in shallow sediments severly limits depth of penetration. They indicated that depth profiles extended to 80 ft. may be obtained in an area not affected by salt water; maximim penetration is between 5 and 20 ft. in areas with highly saline water. Therefore, the effective depth of exploration should be less than 19.7 ft. for EM 31 and the results of this survey reflect changes in the conductivity of shallow groundwater beneath the surveyed area.

Applicability of EM Survey at Cabot Plant

Because a thick, uniform till formation underlies the plant area, depth to groundwater is shallow and the waste stored in the impoundment is hydrochloric acid (HCl) EM survey is suitable to assist in delineating groundwater contamination at the plant. When HCl acid reaches groundwater, the acid is ionized as H^+ and Cl^-. The chloride ion is not affected appreciably by soil fixation processes such as adsorption ion-exchange, precipitation, and biological activity when the chloride-rich groundwater travels through soils or rocks. Once chloride reaches groundwater, it is difficult to remove chloride through natural processes. Thus, chloride-rich groundwater forms a highly conductive contaminant plume which can be identified by a conductivity meter such as EM 31.

The measured high terrain conductivity values at the Cabot plant are primarily caused by mineralized (chloride-rich) groundwater. Buried metal pipes, drums and other objects may affect a measured value. Fences and buildings may have less effects on conductivity values. In order to discount any effects of the above, instructions in operating manual (Geonics Ltd., 1984) have been followed.

A cautionary note should be added that a terrain conductivity survey does serve only as a guide. The results of such a survey should be complemented, checked and corrected by making correlation with the results of groundwater quality analyses from the monitoring wells.

Results and Discussion

Apparent conductivity was measured at 489 stations at the Cabot plant and in the farm field which lies immediately east and southeast of the plant. Based on the measurements, a terrain conductivity map has been prepared (in pocket). It appears that the conductivity values less than 40 millimhos/meter may represent the background which is found primarily in the southern, eastern and northeastern parts of the surveyed area. Groundwater is contaminated in the areas where terrain conductivity exceeds 50 millimhos/meter.

Four areas of high conductivity are identified on the map. One of these is related to a source in the U.S.I. Chemicals Co. property located just west of Cabot plant property. The other three sources are the RCRA impoundment, the solids disposal area and the solid waste disposal site in the Cabot plant (map). The terraine conductivity values up to 265 millimhos/meter have been measured at the western parts of the property. The terraine conductivity decreases eastward and becomes less than 50 millimhos/meter approximately 200 ft. from the western boundary of the Cabot plant property. Shape of the contours and the measured values indicate that contamination originates from the U.S.I. Chemicals Co. property and propagates eastward.

Migration of both the waste fluid from the RCRA impoundment, and the leachate from the leachfields and the solid waste disposal sites cause high terrain conductivity values near these sources. The terraine conductivity contours of high value circle them; however, these contours elongated east-southeast in the flow direction of regional groundwater. The contours of 300, 250 and 200 millimhos/meter are associated with the impoundment. However, the 200-contour forms a circle around both the impoundment and the solids disposal area. Therefore, it is difficult to determine from the available data the eastward extent of contamination from the RCRA impoundment. Probably this contamination reaches to the mid-point between the two 250 millimhos/meter contours at the east of the impoundment. The southerly extension of the 250 millimhos/contour and outward bulging of the 200 and 100 millimhos/meter contours off the southeast corner of the impoundment may not be related to the impoundment and possibly caused by the disposal activities in the past.

The highest terrain conductivity values, exceeding 500 millimhos/meter, are associated with the solids disposal area. It appears that some of the leachate from the facility reaches groundwater beneath it and travels eastward as indicated by the 200 millimhos/meter contour.

The fourth major source of high terraine conductivity is the solid waste disposal site on the east side of the plant which is next to the barbed wire fence. The terrain conductivity values exceeding 100 millimhos/meter are associated with this facility. Although this area is equipped with an underdrain leachate collection system, it appears that some of the leachate from the facility reaches groundwater beneath it and travels eastward. The eastward extension of the 50 millimhos/meter contour beyond this facility suggests groundwater contamination in parts of the farmfield.

In addition to the four major areas of high conductivities, there are a few areas with relatively high conductivity in the plant property (map in pocket). Some of these are associated with the acid storage tank areas located north of the RCRA impoundment. Another high conductivity area is just at the south of the northern barbed wire fence. Terrain conductivities as high as 95 millimhos/meter are identified in this area where there was a fertilizer plant in the past (Crews, personnel communication).

SUMMARY AND CONCLUSIONS

A thick, uniform silty clay/clayey silt till with relatively low hydraulic conductivity underlays the Cabot plant. The main by-product is hydrochloric acid which has been stored in an impoundment prior to injection into one of the two deep wells. The impoundment and a solids disposal area at the plant property are the primary potential sources of groundwater contamination.

An EM survey has been made using EM31 equipment. The apparent terrain conductivity values range from 30 to 510 millimhos/meter. Groundwater is contaminated in areas where the measured value exceeds 50 millimhos/meter. Four areas of high conductivity are identified on the terrain conductivity map. These areas are related to a source in the U.S.I. Chemicals Co. plant and three sources (impoundment, solids disposal area and a solid waste disposal site) in the Cabot Corporation plant. Conductivity contours are elongated in the regional direction of groundwater flow, that is east-southeast from these sources. In addition, there are less significant sources identified near the impoundment and in the northern parts of the plant.

The EM survey suggests that the highest groundwater contamination occurs under the solids disposal area and that the groundwater contamination extends into the farmfield lying immediately east of the eastern barbed wire fence of the plant.

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